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A NORMAL INCIDENCE, HIGH RESOLUTION X-RAY TELESCOPE  
FOR SOLAR CORONAL OBSERVATIONS

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Grant NAG5-626

Semiannual Progress Report No. 6

For the period 1 February 1987 through 31 July 1987

Principal Investigator:

Dr. Leon Golub

August 1987

Prepared for

National Aeronautics and Space Administration

Wallops Island, VA 23337

Smithsonian Institution  
Astrophysical Observatory  
Cambridge, MA 02138

The Smithsonian Astrophysical Observatory  
is a member of the  
Harvard-Smithsonian Center for Astrophysics

The NASA Technical Officer for this grant is Mr. Larry J. Early,  
Code 840.0, Goddard Space Flight Center, Wallops Flight Facility, VA 23337

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## O. Summary

Post-flight analysis shows that all payload systems and subsystems performed well within acceptable limits, with the sole exception of the light-blocking prefilters. Launch, flight and recovery were carried out in a fully satisfactory manner.

The payload was recovered within an hour of set-down and in excellent condition. There was no damage to any major components and minor component damage was limited to the vicinity of the entrance aperture, as anticipated. The film camera was recovered within one hour of launch and was processed soon afterward with the assistance of Sac Peak personnel.

No x-ray images were detected on the processed film. A slight darkening of the negatives near the edge of the frame on the long exposures is attributed to a small visible light leak which reached the film through vent holes at the edge of film camera filter's mounting frame. Postflight filter transmission measurements performed at IBM yielded transmission values of 1% and 3% for the entrance aperture and camera filters, respectively. These filters operate in series in the light path. Preflight measurements of 20% and 32% for the two filters were subsequently shown to be erroneous due to Carbon  $K_{\alpha}$  contamination in the measuring chamber.

The following corrective actions have been taken:

1. The heat rejection and light-blocking function of the filters have been separated, and will be performed by the entrance aperture and camera filters respectively. For ideal filters, this change would increase the x-ray transmission by a factor of three.
2. In comparison with the filters actually flown, removal of the light-blocking Carbon from the entrance aperture produces an additional factor of ten in throughput.
3. Implementation of proper procedures for producing the camera filters permits the desired visible light attenuation with a smaller amount of Carbon than was previously

flown. The increase in x-ray throughput is a factor of five.

The combination of these three steps will increase the x-ray transmission by a factor of 150. In addition, a new developer is now available for our special emulsion which increases the sensitivity of the film by a factor of five, with no loss in resolution. We are performing extensive x-ray tests of the new developer in order to verify this preliminary result.

The entire payload was shipped to the National Synchrotron Light Source at Brookhaven for calibration on the U14 plane grating monochromator. X-rays of the correct wavelength were sent into the front of the telescope and were detected in the focal plane. The wavelength of peak reflectivity agrees to within 0.1% with that of sample flats coated at the same time as the flight optics. Uniformity of the coating, overlap between primary and secondary mirror coatings and absolute reflectivity of the coatings all are in agreement with our previous indirect measurements.

A second success criterion has been added for the next flight. In addition to the multilayer telescope as our primary objective, we have also installed the high resolution detector system into our auxiliary  $H_{\alpha}$  telescope in place of the commercial CCD camera used in the last flight. A new electronics section has been added in order to accommodate the camera electronics and some of the analog circuitry.

This detector is in all respects identical to the high resolution x-ray detector which we plan to fly in the future, but without the phosphor coating at the focal plane. Thus, we will flight qualify the HRX detector on this flight, in addition to obtaining high resolution x-ray images on film.

## I. Preflight Preparation

### A. Multilayer Mirror Fabrication and Testing

The main challenges for fabrication of the multilayer coatings for this experiment were:

1. To produce coatings with smooth, sharp boundaries in order to obtain high reflectivity;
2. Control the thickness and uniformity of the coatings such that both mirrors match the desired emission lines on the Sun;
3. Obtain high yield and reproducibility in the coating process;
4. Test mirrors before the flight in order to predict their performance.

Mirror coatings were tested by several methods: *in situ* reflectivity at the monitor wavelength during deposition, reflectivity at  $\lambda=1.54 \text{ \AA}$  for grazing angles of incidence, and reflectivity for soft x-rays at near-normal incidence using synchrotron radiation. The first of these methods is routinely used during each coating run; however, it is useful only to determine the overall quality of a particular coating run. Such monitoring is used mainly to recognize and correct problems during the multilayer deposition process.

The second method is our primary means of characterizing mirror performance. A reflectometer using  $1.54 \text{ \AA}$  radiation is available at IBM and provides the ability to measure samples with very rapid turnaround time. From measurements of reflectivity *vs.* angle we can predict the normal incidence performance of a mirror, the effective roughness of the layer boundaries, and the thickness errors of the multilayer stack. An example of these measurements is shown in figure 1.

Because we rely heavily on the grazing incidence measurements, it is very important to verify their accuracy in predicting normal incidence performance. Measurements with synchrotron radiation at near-normal incidence (  $0.7^\circ$ , i.e.  $\cos\alpha=0.99994$  ) agree quite well with predictions. Figure 2 shows the measured performance of a "witness" mirror coated during one of the flight mirror deposition runs; the goal was to achieve a peak reflectivity

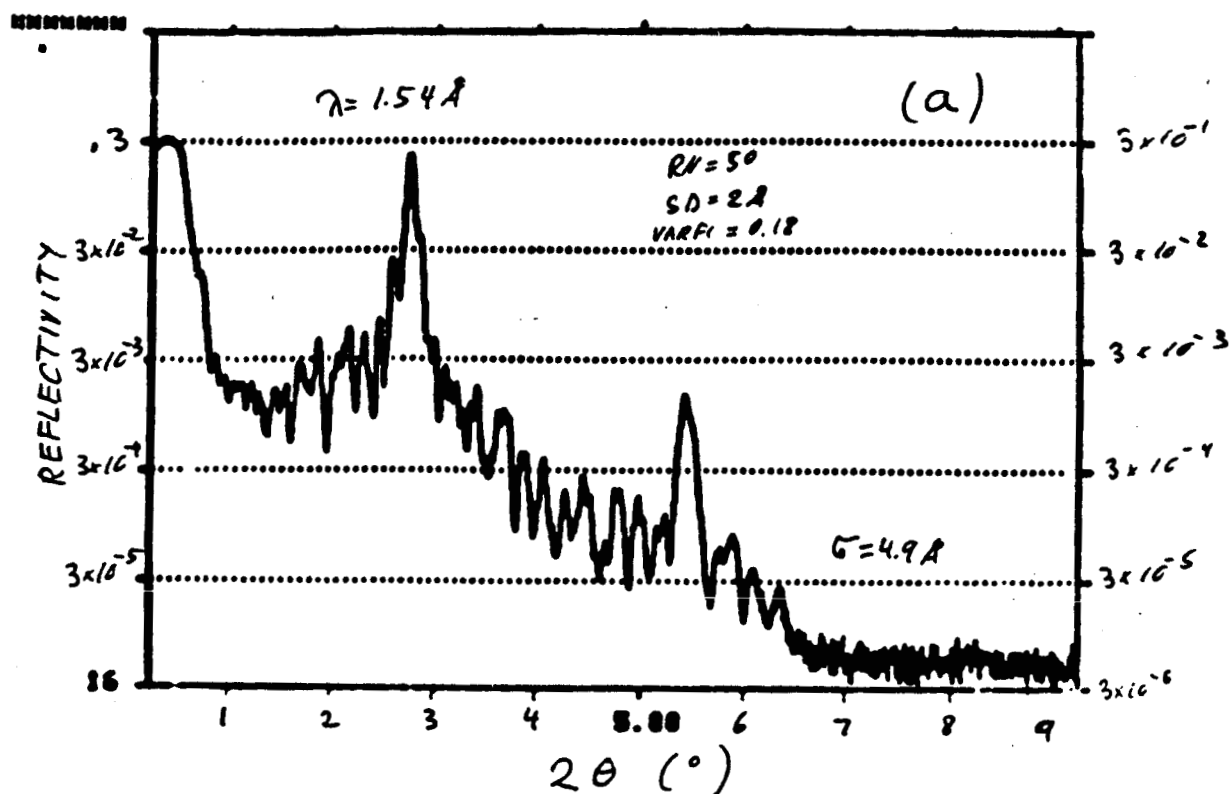


Fig. 1. Grazing incidence reflectivity measurement, showing first and second order diffraction peaks.

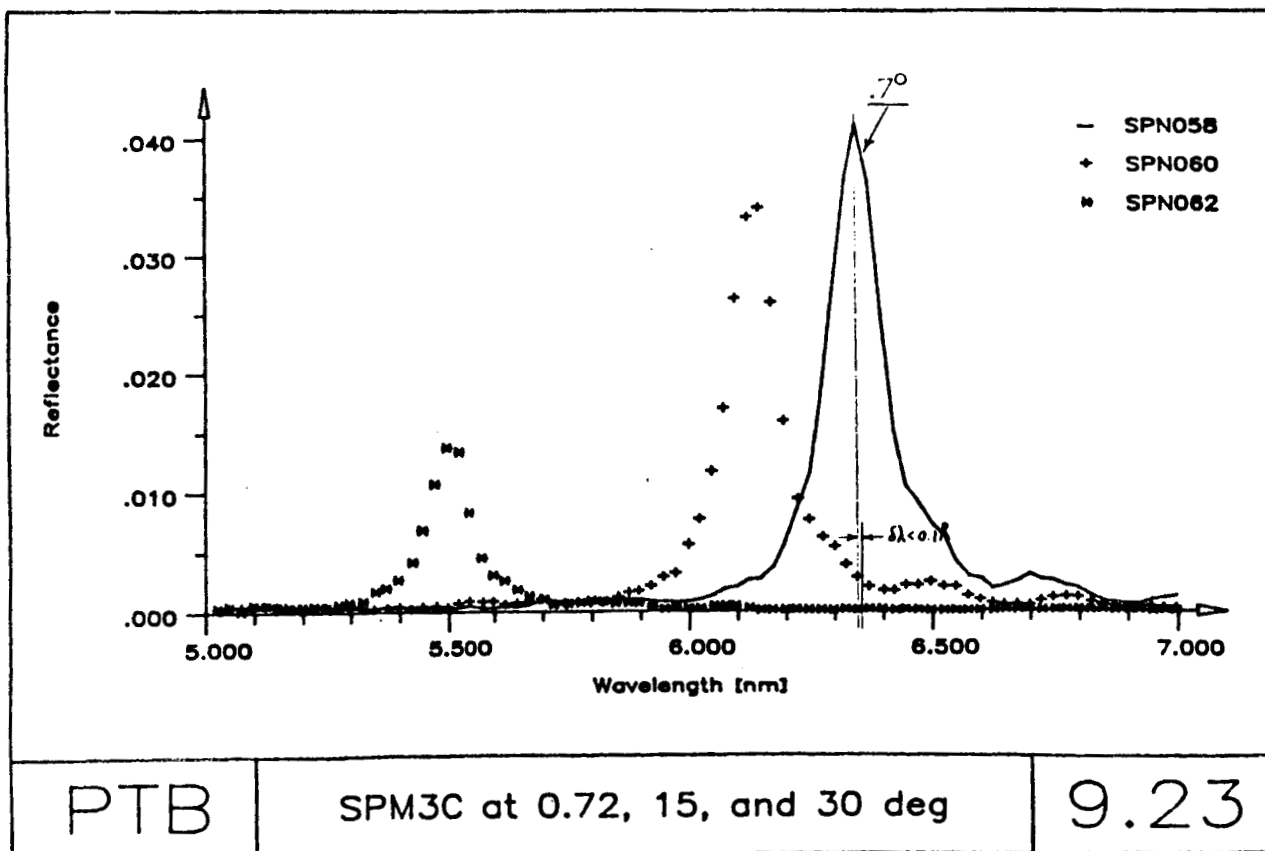


Fig. 2. Normal-incidence reflectivity measurements; peak is within 0.1 Å of predicted position.

at  $63.5\text{\AA}$  and the result shows that this was accomplished to within  $0.1\text{\AA}$  accuracy. The main drawback to mirror testing at synchrotrons is that turnaround time for obtaining results is usually several months.

The value of peak reflectivity for the flight mirrors is about a factor of two lower than expected on the basis of grazing incidence measurements. The difference can be explained if one assumes that the boundary roughness of the multilayer stack increases from the bottom toward the top of the coating; such a result would be consistent with other measurements which have been reported in the literature. At  $\lambda=1.54\text{\AA}$  all layer boundaries contribute because of the penetrating power of the test beam, but at  $63\text{\AA}$  the top layers have considerably more weight. Rougher boundaries near the top of the coating would therefore produce a larger effective roughness and reduce the overall performance.

The uniformity of the coating on the flight primary mirror is shown in Figure 3. The measured values are centered around the desired wavelength of  $63.5\text{\AA}$  and the coating becomes thinner toward the edge of the mirror, as anticipated. Similar measurements for the secondary mirror are shown in Figure 4. Based on these measurements we can calculate the expected performance of the telescope for imaging of the desired coronal lines, and we can also calculate the increase in effective collecting area possible with perfectly uniformity and overlap of the passbands in the two mirrors' coatings. The results are:

- i) A perfectly uniform primary (having the measured peak reflectivity of 4.2%) would have 30% greater effective collecting area than the mirror flown, and
- ii) a similarly perfect secondary would increase the collecting area by an additional 20%.

We consider the achievement of coating uniformity and wavelength accuracy at these levels to be a complete success and entirely satisfactory. However, the factor of two difference in reflectivity between the expected and achieved coatings is considered to be marginally satisfactory. We will be carrying out additional coating runs and testing in an attempt to improve the reflectivity values. The possible gain in total effective collecting



PRIMARY 2:●●, Si:○○, FLOATGLASS: □□

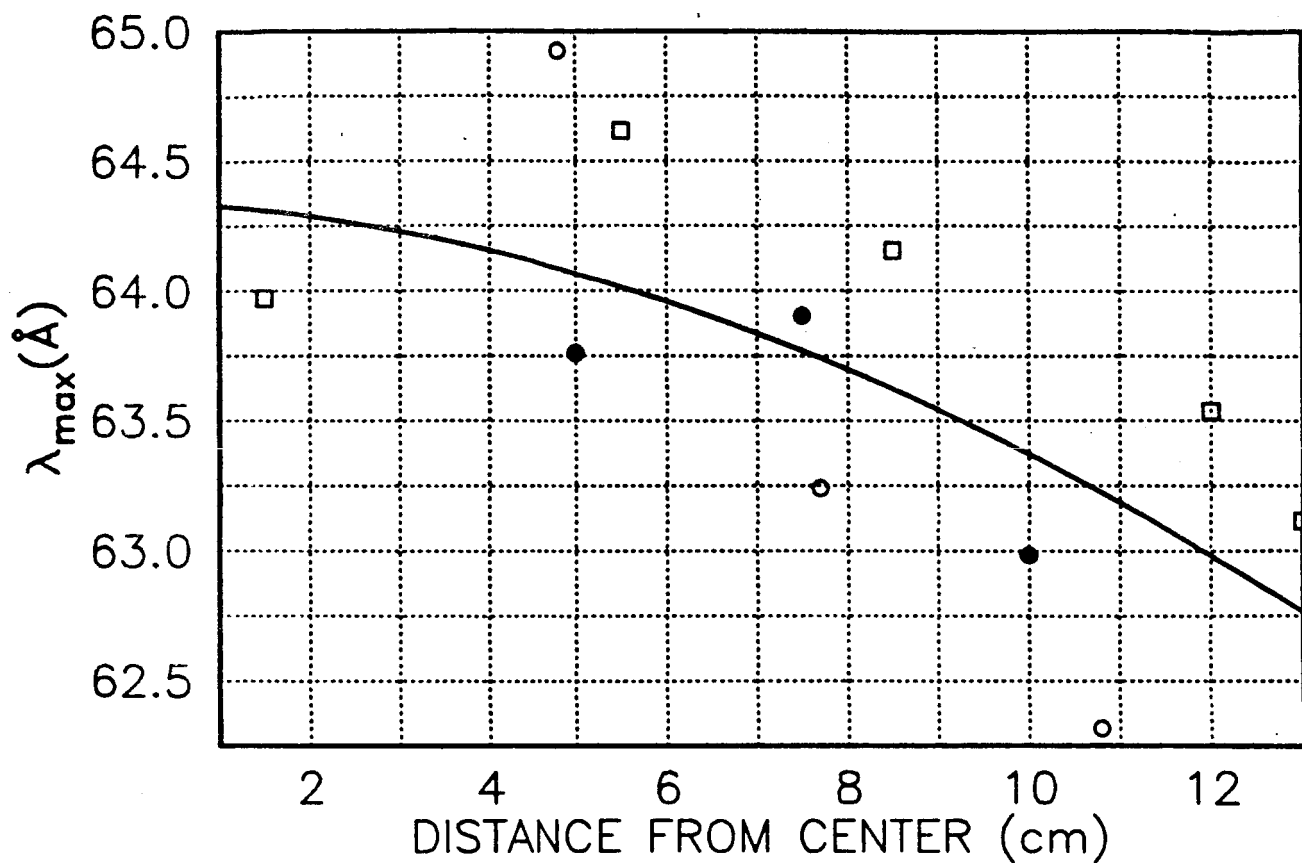


Fig. 3. Test results showing coating uniformity of the NIXT primary mirror; also shown are test results on Si wafers and on float glass samples. Solid curve shows expected result.

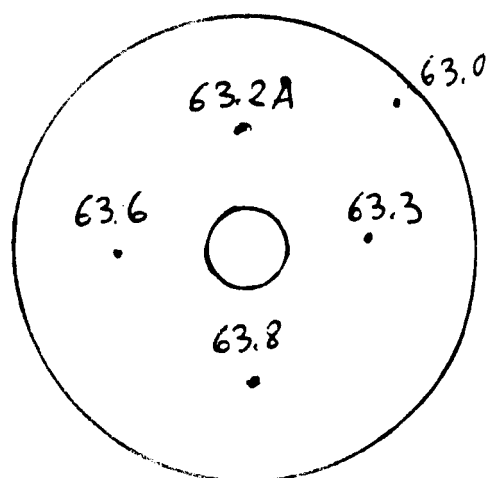


Fig. 4. Coating uniformity of the NIXT secondary mirror, showing wavelength of peak reflectivity at five positions on the mirror.

area which we are seeking is thus a factor of four, since there are two reflections in the telescope.

## B. Integration and Testing

The NIXT experiment development required state-of-the-art technological innovations in the fields of:

- a. multi-layer coatings
- b. mirror fabrication
- c. large aperture X-ray filters
- d. telescope structure and optical mountings
- e. film - testing and evaluation

A detailed program plan was developed to properly test all of these new technology areas in order to insure proper flight performance. In addition, it also covered checkout of the entire experiment, thereby evaluating total system performance.

The major subsystem testing performed has been listed in Table 1, with the test objectives and results. Similarly, all system level testing performed during the final assembly phase is listed in Table 2. Presenting the testing performed in this fashion hopefully will allow the reader to better interpret our approach and the steps which were taken in order to qualify the experiment.

Table 1  
Sub-Assembly Testing

<u>Unit Under Test</u>	<u>Type of Test</u>	<u>Test Objective</u>	<u>Results/Comments</u>
Telescope Tube	Optical Alignment Measurements	Bond: 1. G/E Tube to Base Flg 2. Secondary Mtg's to Tube	1. Tube Centered $\lambda .002$ 2. Secondary Parallel Mounts Focus Location Correct Parallel to base within 5 arcsec Bond Samples Str. Tested OK
Secondary Mirror Truss	1. Load/Deflection 2. Fit check	1. Measure 10g deflection 2. Mates with Telescope Tube and Secondary Mirror Assembly	1. Better than predicted (stiffer) Less than 15 arcsec 2. Less than 24 arcsec OK
Liss Sun Sensor Mount	1. Load/Deflection 2. Fit check	1. Measure 10g deflection 2. Mates with Telescope Tube and Secondary Mirror Assembly	1. 10g deflection 2. OK
X-ray Prefilter	Vacuum Solar illumination	Measure filters melting point	Filter remained unaffected by illumination of 3 solar constraints
X-ray Prefilter	See Paragraph ____ for additional comments.		
Primary Mirror Subassembly	Vibration	Qualify primary mirror mount to rocket vibration and optical requirements.	Tested 3 times, original banded design was abandoned, classical 3 point mount passed successfully on second attempt.
Camera	Vibration	Qualify camera to rocket vibration requirements.	Camera was purchased from Hasselblad to these spec's. Hasselblad tested and qualified camera.

Table 1 Cont.  
Sub-Assembly Testing

<u>Unit Under Test</u>	<u>Type of Test</u>	<u>Test Objective</u>	<u>Results/Comments</u>
Secondary Mirror Sub-Assembly	Optical Measurements	1. Measure range and resolution of tilt adjustment 2. Defocus due to tilt 3. Tilt Motion due to locking	1. Range 31 arc-min. OK Resolution 0.3 arcsec OK 2. Unmeasurable 3. No measurable change
Secondary Mirror Sub-Assembly	Random vibration and load/deflection.	Measure change in secondary position.	No measurable position change.
Hx Video Camera	Solar Imaging	Confirm optical alignment, focus, Hx filter operating, camera sensitivity and resolution.	Sunspot observed, System OK
Vacuum Pressure Gauge	1. Vibration 2. Vacuum (Pressure)	Qualify to required vibration levels. Measure calibration curve from Vendor.	Qualify by vendor. Vendor calibration correct.
Electronics	Standard electronic functional tests at card and system level.	Qualify electronics operation and interface.	Standard problems, all resolved.

Table 2  
NIXT System Level Testing

Configuration	Test	Test Objective	Results/Comments
Rocket Skins and Bulkheads assembled empty	Vacuum Leak Test	Qualify rocket skins, door and end bulkheads as a vacuum vessel	Leak tight Pressure Rise $\approx 80\mu$ in 24 hours. Attributed mostly to outgassing.
Assemble Experiment within rocket sections, using equivalent test optics (flats)	FIT Check	Assembly of experiment to flight configuration	Completed after some minor modifications
As Above	Visual and Electronic Measurements	Confirm SPARC'S and TM interfaces	Completed
As Above	Vibration Test 3 Axis Per WIFF Specification	Qualify Experiment and measure optical displacements and angulations. Between Pri-secondary mirrors.	No problems observed pass test without incident. No optical motions detectable.
Primary Mirror Assembly	Mount Distortion	Determine distortion of multi-layer coated primary mirror due to mount.	$\lambda/2$ arcsec's (Done by interferometric and deflection pattern interpretation.)
Secondary Mirror Assembly	Mount Distortion	Determine distortion of multi-layer coated secondary mirror due to mount.	No measurable effect. (Done by comparable interferograms.)

Table 2 Cont.  
NIXT System Level Testing

<u>Configuration</u>	<u>Test</u>	<u>Test Objective</u>	<u>Results/Comments</u>
Telescope fully assembled less camera and removed from rocket skins	Optical Alignment	Align secondary mirror to primary to required tolerances.	Secondary centered to less than .0005 inches.
As Above	Optical Focus	Focus Telescope and place camera film plane at that focal position.	Telescope focal plane determined and camera positioned.
As Above	Image Evaluation	Determine X-ray Blur circle.	Determined to be between 0.2 to .3 arcsec's.
Flight Configuration	Electronic Functional	Qualify electronic operation	Repeated numerous times without problems.

### C. WSMR Activities

The experiment was shipped to WSMR on Saturday 2 July 1986. Experiment integration activities began on Monday 14 July and continued thru 25 July with all integration activities being accomplished excepting tower installation and launch. These activities were postponed because of the lack of solar activity.

The experiment was unpacked immediately upon arrival at WSMR and visually inspected; no problems were observed. The optical alignment and focus were then checked and determined to be identical to the pre-shipment values. A full electronic functional test was then performed without any problems in evidence. The integration testing was then undertaken and the results are shown below, grouped by engineering discipline and arranged in the order undertaken for that discipline.

MECHANICS. The tests conducted were:

- a. Weight, C.G. (Experiment only)
- b. Mechanical Fit Up
- c. Bend Test
- d. Spin Balance
- e. Moment of Inertia (MOI)
- f. Mechanical Random Vibration - 3 Axis
- g. Second Spin Balance
- h. Second MOI

Weight, C.G.:

The experiment weight was 2.65 pounds heavier than estimated, 334.45 vs 336.8 pounds. The center of gravity was at the proper station.

Mechanical Fit:

The mechanical envelope was exactly as specified and mated properly with the for-

ward telemetry package and aft ignitor housing. All Sparcs, Tower and Telemetry stations were correct. No problems were experienced in this area.

Bend Test:

The bend test proved that the rocket stiffness (caliber) was well within acceptable limits.

Spin Balance:

The spin balance went normally with the addition of approximately five pounds of trim weight required to balance.

Moment Of Inertia (MOI):

The MOI test went without incident and the values were forwarded to NASA Wallops (WIFF) for verification. WIFF determined that additional weight (20 pounds) was required just forward of the ignitor housing to insure proper re-entry dynamics. This was a result of poor stacking dimensions, weight and center of gravity nomenclature of the equipment forward of the experiment. This necessitated the remeasurement of the spin balance and MOI after weight addition.

Second Spin Balance:

The spin balance was repeated with previous weights removed. The weights were then tailored slightly and re-installed. A spin check was then performed and the balance was within acceptable limits.

Second M.O.I.:

The measurements were again forwarded to WIFF which subsequently approved them for flight.

OPTICAL:



The following optical tests and alignments were made:

- a. Experiment alignment and focus
- b. Experiment alignment to Sparcs
- c. Experiment alignment to H $\alpha$  TV and Sparcs

#### Experiment Alignment and Focus:

The experiment alignment and focus were checked twice. First, upon receipt of the experiment at WSMR after shipment from IBM. The second check was after the mechanical random vibration test. Both these checks indicated no change from the precise alignment and focus done at IBM.

#### Experiment Alignment to SPARCS:

The experiment was aligned to SPARCS using LSMC personnel and equipment. The axis were co-aligned to within 5 arcsecs.

#### Experiment Alignment to H $\alpha$ and SPARCS:

The H $\alpha$  TV was aligned to SPARCS such that it was along the pitch axis and 3 arc minute in the + yaw axis. This was deemed adequate and verified by using the LSMC sidereostat and simultaneously viewing and attenuated solar image in the telescope's film plane and the Hx video monitor.

#### ELECTRONICS:

The following electronic tests were conducted with the following results:

- a. Experiment electronic functionals
- b. Electrical integration test
- c. Payload end to end

#### Experiment Electronic Functionals:

The experiments electronic health was tested daily and after any test. All these tests indicated proper electronic function.

#### Electrical Integration Test:

Several problems were uncovered and corrected. They all were the result of wrong pin (wiring errors) assignments or faulty connector pins. The only design correction required was the 30 second valve open gate. LSMC was supplying a momentary pulse which had to be converted to a constant level change.

#### Payload End to End:

This test was conducted several times with no experiment problems evident.

#### Launch Sequence:

The integrated experiment was moved to the VAB for motor installation and then erected in the tower. This operation went smoothly without problems. The vacuum system was attached to the experiment and a leak test performed. A filter light leak test was then performed. The filters were free of pinholes or other light leaks.

The experiment was then tested electronically using both telemetry and the land lines.

Several minor problems occurred; these were:

- a. The land lines were saturated by water from recent storms. This caused the impedance to be too high for our GSE test console to drive. The data was stripped off from the Lockheed console and testing proceeded. After a day or so of use, the land lines dried out sufficiently to become operational. All systems were then found to be operating correctly.
- b. Telemetry checkout went smoothly and no problems occurred, however, problems surfaced when the test procedure was performed out of sequence.

## II. Postflight Analysis

### A. Engineering Analysis

Upon return of the experiment following recovery, and with the knowledge that no images were recorded on the film, a set of tests were conducted to minimize the number of possible causes. These tests were:

- a. Inspection of Optics
- b. Alignment of telescope to Sparcs - Fine Sun Sensor (LISS).
- c. X-ray Camera Operation

Inspection revealed that the optics were intact i.e. no visual damage. In fact, the only damage observed was to the SPARCS Mass-Coarse Sun Sensor. The rocket's open end landed on a desert bush with a surrounding soft sand mound. These articles pushed the forward aperture plate into the sensor, breaking its front window.

A solar image was folded into the telescope using the guided Lockheed siderosat. The solar image was attenuated for intensity and centered in the X-ray camera's film plane. The SPARCS fine sun sensor was then powered by a Lockheed GSE unit and its error signal read out. The sensor output was at null, indicating perfect alignment.

The X-ray camera was cycled by GSE and indicated proper operation. The film camera frame counter also showed the appropriate number of exposed frames and no tearing of the film at the spool sprocket holes. Therefore proper film advancement took place.

Post flight review of all housekeeping data showed that the experiment operated flawlessly. Analysis of housekeeping data has confirmed proper operation of the NIXT experiment functions and for all NASA supplied equipment (SPARCS, PSL, etc.) Reduction of engineering records for vacuum pressure and thermal isolation of the telescope reveal the following:

- 1) Vacuum Pressure:

The X-ray beam path within the telescope section is 16.1 feet requiring that the vacuum pressure be less than  $100\mu$  in order to eliminate atmospheric absorption of the incoming photons. The payload was evacuated in the tower and sealed by closing a valve one hour before launch. This valve was opened by remote command during the ascent phase of the launch. The vacuum pressure record for our flight is as follows:

Time	Reading (Volts)	Pressure (Microns)	
T-120 min	3.65	6.6	Tower Pump System
T-90 min	3.39	5.8	Tower Pump System
T-68 min	3.29	5.6	Valve @P/L Separate Pump
T-30 min	4.35	7.2	
T-0	5.65	11.6	Launch
T+30 sec	5.80	12.0	Vacuum Valve Open
T+60.8 sec	5.21	10.5	Motor Separation
T+90 sec	5.10	10.25	Sparcs Fine Mode
T+150 sec	3.57	6.4	X-ray Camera Start
T+200 sec	3.40	6.0	
T+300 sec	1.99	3.0	
T+400 sec	1.62	2.3	
T+500 sec	5.10	10.25	End of Data Taking

## 2) Thermal Performance.

Flight data from the eight temperature sensors indicated that the thermal design of the NIXT experiment was effective and performed as expected. The two sensors on the external skin peaked at about  $80^{\circ}\text{C}$  200 seconds into the mission, then decreased to  $75^{\circ}\text{C}$  just before reentry. The heat shield between the skin and telescope tube rose about  $7^{\circ}\text{C}$  during the flight, and the tube temperature increased less than  $0.3^{\circ}\text{C}$ , indicating that the shield performed its design function. The prefilter frame rose  $2\text{-}3^{\circ}\text{C}$  during launch, then about  $12^{\circ}\text{C}$  more during the period of solar exposure. The main mounting flange temperature increased about  $2\text{-}3^{\circ}\text{C}$  between 100- 200 seconds as heat from the skin was conducted into it. Other internal experiment temperatures rose less than  $2^{\circ}\text{C}$  during the flight.

The reentry heating pulse caused a temperature increase of about  $6\text{-}8^{\circ}\text{C}$  in most parts of the experiment, with two exceptions: the main mounting flange rose about  $15^{\circ}\text{C}$  and the

filter frame about  $35^{\circ}\text{C}$ . Temperature decay was much more pronounced after reentry, so that at the end of data at 750 seconds, the external temperatures were about  $60\text{-}65^{\circ}\text{C}$ , internal temperatures in the  $20\text{-}40^{\circ}\text{C}$  range.

## B. Prefilter Testing

After recovery of the payload, small pieces of the entrance aperture prefilter remained intact. Several of these sections were removed and brought back for x-ray testing at IBM and at the CfA. Tests in Cambridge yielded transmission values of 20%, while tests done at IBM gave transmission values of 1%. The backup filter located at the film camera survived intact and was returned to IBM along with the remainder of the experiment section. This filter was measured by Dr. Spiller as having a transmission of 3%.

Further tests and discussions showed that the x-ray measurements done at CfA were actually dominated by C K $\alpha$  radiation at 44A, rather than the expected 63.5A wavelength. The IBM tests were done using a Boron target which produced predominantly B K x-rays at 68A. The difference in mass absorption coefficients for Carbon, Aluminum and Polypropylene in going from 44A to 68A is exactly sufficient to explain the discrepancy between the x-ray transmission values measured at CfA and at IBM.

Our conclusion from these tests is that the amount of Carbon on the flight filters was an order of magnitude greater than predicted, a total of  $12\mu$  rather than  $1.5\mu$  on the two filters combined. The overall throughput of the two filters in series was thus  $3 \times 10^{-4}$ , a factor of 200 lower than expected. The cause has been traced to improper adherence to the filter production procedures which had been established, combined with erroneous measurements due to contamination of our test chamber by the shorter wavelength x-rays.

By reviewing and reestablishing proper manufacturing procedures we have been able to produce filters which have a factor of four less Carbon than the ones flown. The 68A transmission of these filters is 15% vs. the value of 3% for the flight filter. We are thus able to recover a factor of 5 in throughput by rigid adherence to proper manufacturing methods. We also note that a transmission of 15% at 68Å implies a transmission of 20% at 63.5Å; we will, however, continue to use the lower value in these estimates.

In addition, postflight evaluation has shown that it is no longer necessary to coat both the entrance aperture and backup filters with Carbon. The front filter need only be Aluminized for

heat rejection and the bulk of the light-blocking function can be done at the camera filter. This change removes an additional  $6\mu$  of Carbon from the light path, which will in practice raise the transmission of the front filter from 1% to 40%.

The total increase in throughput with these changes is a factor of 200, bringing the filter performance up to the level which had been expected before the first flight.

This improvement is viewed by us as being satisfactory and is acceptable for a reflight. However, there are also several potential improvements which could be made and which we are investigating:

- i) A perfect, uniform Carbon layer would accomplish the necessary light blocking with only 60% of the amount of Carbon which we are currently putting on the filters. Thus it is possible in principle to gain a factor of 1.4 in throughput by improving the Carbon deposition.
- ii) The Polypropylene substrates are  $1.2-1.3\mu$  thick and have more than adequate strength. Tests have shown that it is the best material for the filters (compared with Mylar, Lexan and others) and that we could use  $3/4\mu$  PP safely. We are thus investigating whether and how thinner PP films can be produced. The potential gain in throughput for two such films in series is a factor of 1.5.

The combination of these two improvements would yield an additional factor of two in x-ray throughput. We view such an improvement as highly desirable and are vigorously pursuing various avenues for achieving these results. If there appears to be a possibility of obtaining or producing filters with these improvements we will consider delaying the next flight for a reasonable length of time in order to install the improved filters.

### III. Refurbishment and Reflight

#### A. Payload Calibration at the Brookhaven NSLS

Our experience has shown that the only way to measure the x-ray performance of multilayer mirrors is to test under exactly the conditions for which they will be used. Thus, mirrors intended for use at normal incidence must be tested at that angle; indirect tests have been found to be misleading and can produce results which are incorrect by large factors.

In order to calibrate the NIXT payload we proposed for beam time at the Brookhaven synchrotron (NSLS), which has as one of its facilities a plane grating monochromator. This is a tuneable x-ray source with moderate wavelength resolution and which has been calibrated to high accuracy. The payload was shipped to Brookhaven and mounted at the exit of the U14 monochromator, using front and rear bulkheads which had been manufactured for this test.

The NSLS requires an ultra-high vacuum of  $10^{-10}$ , which is far beyond the design of the NIXT payload. However, we were able to install a silicon nitride window between the telescope and the monochromator and all measurements were done through this window. The size of the window ( $200\ \mu$ ) determined the wavelength resolution of the system and its position away from the usual exit slit necessitated recalibration of the monochromator. The payload was thus tested in its flight configuration, under conditions which simulated as nearly as possible the actual flight environment.

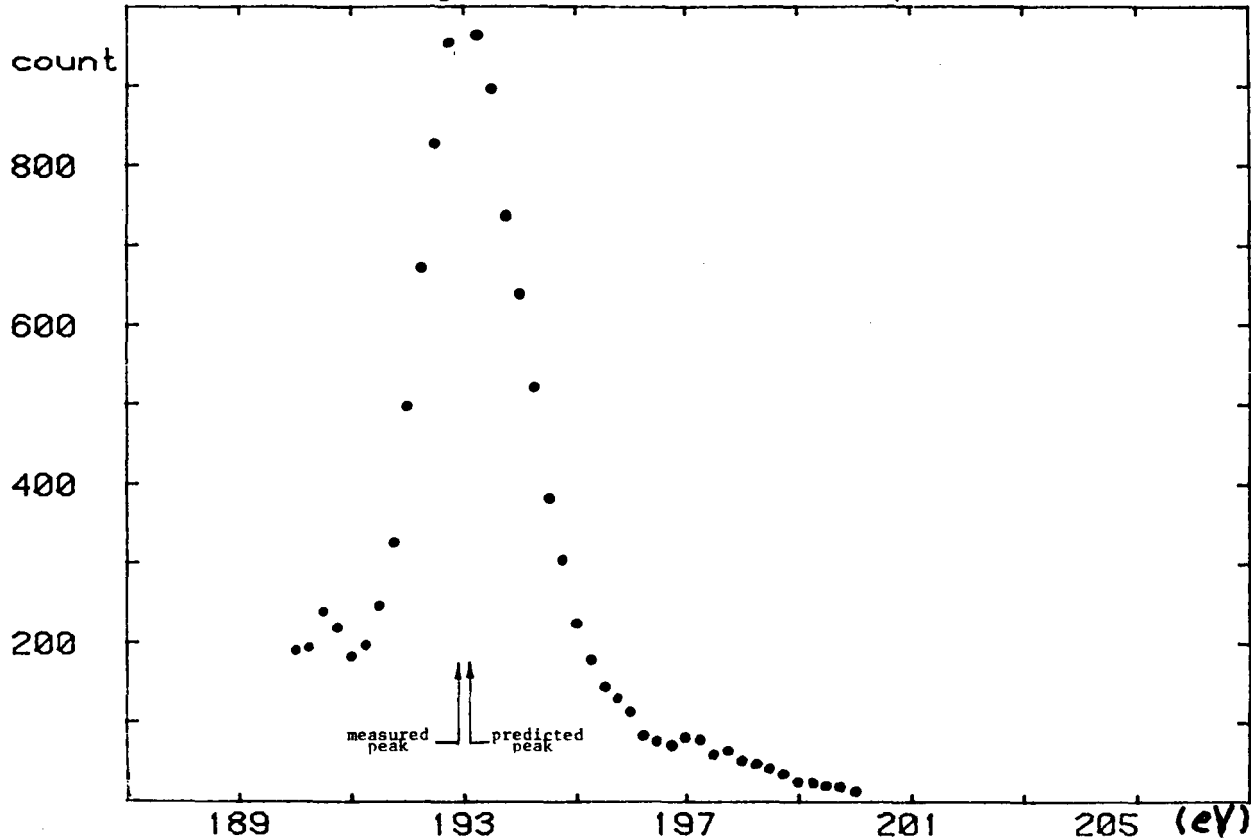
A typical measurement is shown in figure 3-1, made at a radial distance of 7.5 cm from the optic axis of the telescope. The width of the curve (FWHM) is 1.3%, which implies that  $\sim 80$  layer pairs are contributing to the reflectivity. This is consistent with our discussion in §II in which we have concluded that the higher than expected boundary roughness prevents the bottom-most layers from seeing the diffracted beam.

The peak of the reflectivity curve is at 193 eV, which agrees precisely with measurements made on the "witness" mirrors. The latter were small strips of silicon wafer which were glued onto the primary before deposition of the multilayer coating; they were subsequently removed



from the mirror surface and have been used for testing the coating. In particular, these small mirrors were tested at the synchrotron facility in Berlin as described in §II.

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The excellent agreement between the flight mirrors and the witness mirrors allows us to perform any additional tests on the smaller flats. These tests include not only reflectivity measurements, but also tests for drift in wavelength, changes in roughness and several other effects which might degrade the multilayer performance.

#### B. Flight Readiness Review.

A flight readiness review was held at the Wallops Flight Facility on 21 July 1987. At this time a preliminary launch schedule was set, with prelaunch activities beginning in late September of 1987 and launch planned for October; the actual launch date is strongly dependent on Solar activity levels, so that a precise date cannot be set at this time.

Review of our present status and of the activities remaining until launch indicated that

there should be no difficulty in meeting the schedule. The experiment received slight damage, as stated previously, with a great deal of dirt and dust scattered throughout the telescope section. A complete disassembly and thorough cleaning have been carried out. Disassembly was also required in order to remove the optics for visual inspection and for x-ray wavelength testing of the individual mirrors as part of the x-ray calibration.

The electronics section was totally sealed and was functionally checked out post flight. Also the  $H\alpha$  filter, Pulnix camera and X-ray camera have all been functionally operated and are all deemed flight worthy. The  $H\alpha$  filter was sent to its manufacturer for a complete overhaul and wavelength calibration and it has now been returned to SAO.

A new electronics skin section has been built for the high resolution camera electronics and we are presently completing construction of the redesigned circuit boards. An S-T vidicon tube is being installed in the  $H_{\alpha}$  telescope and all of the cabling for the new camera head has been wired into the payload.